Interreg
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LOGISTICS AND TRANSPORT

Air transport technology management

UNIVERSITY OF APPLIED SCIENCES UPPER AUSTRIA

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CONTENTS

1. THE IMPORTANCE OF AIR TRANSPORT

1.1. Air transport

Air transport is an integral part of transport infrastructure and is an important sector of the economy. International air transport has a major influence on the development of international relations and cooperation on two basic levels:

- socio-political;
- economic.

In general, we can say that air transport contributes to the creation of national GDP, in particular through the emergence of new services and the aerospace industry, creating jobs and enabling the rapid and safe transport of people and things over longer distances.

Air Transport in Numbers

Air transport comprises the transport of about 9.5 million people per day (approximately as much as in 1947 for the whole of this year) and has an annual energy consumption of approximately 56 TWh.

There are over 49,000 airports in the world, most of them (about 15,000) located in the United States with up to 4,000 aircrafts carrying 61,000 passengers moving every second over the air space. The busiest airports are in cities like Atlanta, Chicago, London, Tokyo, Los Angeles, Dallas and Paris.

Air transport is one of the safest modes of transport at all: 539 people died in air accidents in 2008, i.e. one death per 1.3 millionth flight. Fewer people died as a result of air crashes than on Czech roads in the given year.

1.2. Basic Characteristics of Air Transport

- Unlike land-based modes of transport, the airway is spatial and uses a large part of the airspace of the troposphere.

- Aviation means of transport (airplanes) implement their flight due to the lift force acting on the carrier surfaces of the aircraft (mostly wings).

- It allows the transport of persons, goods and animals at high speeds over long distances.

- It allows the transport of persons, goods and animals where land transport routes are not available.
- It is one of the safest transport systems.

- Other uses of air transport: medical interventions, aerial work in agriculture, aerial

photography, fire-fighting and their localization, active and passive tourism, sport flying, etc.

Fundamental elements of the air transport system include:

- **Airplane and**
- **Air transport infrastructure:**

    - Airports and technical facilities
    - Controlled airspace
    - Air traffic control

1.3. Basic Classification of Air Transport

- **Military aviation** is based on the requirements of country protection and is governed by special military regulations and regulations of the Ministry of Defense.

- **Civil aviation** is the subject of a number of international treaties and extensive international cooperation. Civil aviation means air operations operated in the Czech Republic by civil aircraft for civilian purposes and also activities operated by Czech aircraft for civilian purposes abroad. Within civil aviation we can distinguish two areas of air transport:

    - Commercial air transport
    - General Aviation

Commercial Air Transport
Commercial air transport is the most important part of civil aviation and provides aircraft for the transport of persons, goods and mail for a fee. We divide it according to various aspects:

- Personal and freight according to the type of transport.
- Regular and irregular according to the way of operation.

tional and international according to its range.
- Small and large commercial air transport according to the type of operation.

General Aviation

General aviation is a part of civil aviation and includes:

- **Aviation work** – the use of aircraft to operate for a fee;
- **Aviation activities for the state's needs** – flights for the transport of state officials;
- **Aviation activities for personal use** – business or other activities, according to special regulations;
- **Recreational and sport flying** – non-profit flying;
- **Air public performances and air races**.

2. THE HISTORY OF AIR TRANSPORT

2.1. Early Beginnings of Flying

The first person to start dealing with flying from a scientific point of view was Leonardo da Vinci (1452-1519).

The first serious attempts were made in the 18th century in Europe with hot air balloons - the Montgolfier brothers (1783).

The first manned airship was built in 1852 by Henri Giffard, but its steam engine did not provide enough power.

It was only with the invention of the combustion engine that new possibilities arose - the first controllable airship with the Brazilian combustion engine by Albert Santos Dumont took off in 1898.

2.2. The Origins of Fixed-Wing Aircraft

Various constructions of "gliders" with fixed wings were created by pioneers at the end of the 19th century. - The best-known pioneer in the area of gliders was Otto Lilienthal.

The first airplane motor flight in history was carried out by **Wilbur and Orville Wright** from the United States in 1903.

In Europe, the pioneer of aviation was particularly **Louise Bleriot**, who crossed the English Channel with his Model XI machine on July 25, 1909.

In Bohemia it was **Ing. Jan Kašpar** who performed the first flight in Pardubice with Blériot aircraft.

2.3. The Origin of Transport Aviation

The first airlines were established in Europe in 1919. The used technology first included military airplanes and airships followed by the creation of airplanes purely for transport purposes.

In 1924, several British companies merged into Imperial Airways. Two years later there was a similar merger of German companies into a single one called Deutsche Luft Hansa.

The first airline in Czechoslovakia was called Czechoslovak State Airlines, founded in 1923.

The period before World War II can be described as the era of large propeller transport aircraft.

2.4. Post-War Development of Air Transport

A major breakthrough in commercial air transport was brought by development and use of jet engines developed during World War II.

The first jet aircraft for civil air transport was the British airplane Comet, which took off in 1949.The use of jet engine enabled the acceleration of air transport.

Air transport, particularly in the 1960s and 1980s, saw a surge in transport volumes following the newly developed aircraft.

2.5. Modern Aviation

The Concorde was the first supersonic civilian airliner. At present, supersonic air transport has been dropped.

Large-capacity airplanes are created for both passenger and freight transport.

The global air transport market shows growth (in terms of the number of passengers transported).

The largest growth in the air transport market in the following years is expected in the Asia region.

It is expected that by 2034 the number of passengers in air transport will reach 7.3 billion passengers.

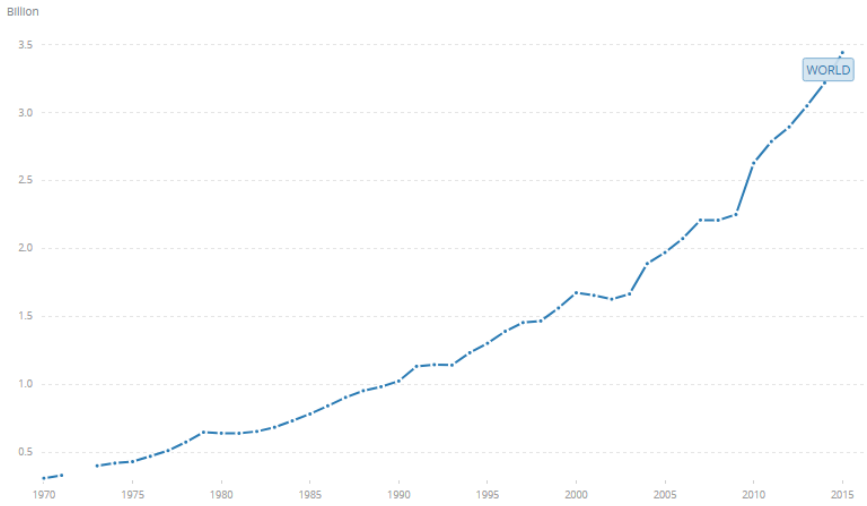

Fig. 1: Development of growth of transported passengers in air transport (in billions of passengers). Source: ICAO

3.INTERNATIONAL COOPERATION, AIR TRANSPORT CONVENTIONS AND REGULATIONS

„ WHEREAS the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world, yet its abuse can become a threat to the general security; and WHEREAS it isdesirable to avoid friction and to promote that cooperation between nations and peoples upon which the peace of the world depends; THEREFORE, the undersigned governments having agreed on certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically; Have accordingly concluded this Convention to that end."

Chicago Convention on Interantional Civil Aviation Preamble

3.1. International cooperation

Important international agreements and milestones in international cooperation in the historical context:

- On October 13, 1919, 26 states were signatories of the "**Paris Convention**" which, among other things, introduced regulations for the use of airspace.
- In 1919 a voluntary International Air Transport Association (**IATA**) was established in the Hague (Netherlands).
- October 12, 1929, a "**Warsaw Convention**" was drafted in Warsaw, relating to the international transport of persons, luggage and goods for reward.
- On December 7, 1944, 54 states signed the "**Chicago Convention**" in Chicago (USA).
- In 1945 the **International Civil Aviation Organization** (**ICAO**) was established.
- In 1952 the "**Rome Convention**" was signed. This is a convention on compensation for damage caused by the operation of a foreign aircraft to third parties or to a country.
- In 1953 the „**Geneva Convention**" was drafted. It established an international rules on the recognition of aircraft rights in order to avoid conflicts of law between individual Contracting States.

- In 1954, the **European Civil Aviation Conference** (**ECAC**) was established at the initiative of the Council of Europe to promote the safe development of the European air transport system.

- In 1955, the "**Hague Protocol**" was signed in The Hague, which serves to amend the Warsaw Convention – it was necessary to adapt air transport requirements and conditions to post-war conditions.

- In 1960, the **European Organization for the Safety of Air Navigation** (**EUROCONTROL**) was established by the European Community within the Eurocontrol Convention.

- In 1963, the "**Tokyo Convention**" was signed. This Convention defines procedures within the "fight against offences and certain other acts committed on board aircraft". This was triggered by the situation in the 1960s, when the abductions of aircraft and passengers were growing.

- Since 1970, the Joint Aviation Authorities (JAA) of the European States have been creating conditions for the implementation of the Joint Aviation Regulation (JAR).

- In the 1990s, ECAC has developed and implemented the European Air Traffic Control Harmonization and Integration Program (EATCHIP).

3.2. National legislation

As a result of international co-operation at the highest level, there are a number of regulations, documents and standards that individual countries (ICAO members) and their air carriers are committed to comply with.

Individual countries are acceding to these conventions and bilateral agreements - building on them national standards and laws to which they then apply their specifics, peculiarities and requirements.

3.3. The Civil Aviation Act

The Civil Aviation Act was promulgated in the Czech Republic under the number 49/1997, Coll. and several times amended.

The requirements of the international Convention on International Civil Aviation and other international conventions are implemented in the law.

Annexes 1 to 18 of the Chicago Convention (ICAO Annexes) specify activities and standards in international civil aviation. The Ministry of Transport of the Czech Republic declares it in the form of revenues as so-called aviation regulations. The basic series of aviation regulations has the designations L1 to L18.

4. AIR TRANSPORT ORGANIZATIONS

4.1. International air transport organizations

The international character of air transport has led to requirements for unification of construction of airports, air traffic control, passenger check-in and other air transport related activities.

There have been many organizations in the aviation industry. It is possible to distinguish them according to the character of individual members:

- **Governmental organizations** (the members are individual governments)
- **Non-governmental organizations** (the members are legal entities or natural persons)

4.2. Important governmental organizations

ICAO - International Civil Aviation Organization. This organization was set up in 1944 at the Chicago Civil Aviation Conference as a government-funded United Nations agency. The primary objective of ICAO is to develop civil aviation principles based on the principles underpinning the UN to support the development of international aviation. Any State that is a member of the United Nations may be admitted as an ICAO member. Its headquarters is in Montreal.

ECAC - European Civil Aviation Organisation – founded in 1955 with headquarters in Paris.

Eurocontrol - European Organisation for the Safety of Air Navigation.

EASA - European Air Safety Agency - is the independent European Aviation Safety Agency set up by the European Commission in 2003 with legal, administrative and financial autonomy.

4.3. Important non-governmental organizations with global scope

IATA (International Air Transport Association) - a voluntary organization of air carriers.

ACI (Airport Council International) – covers the issue of building airport infrastructure, airports operational procedures and their unification, economy of airports, etc.

IFALPA (International Federation of Air Line Pilots Associations) – defends the interests of pilots against carriers and governmental authorities.

ITA (Institut du Transport Aérien) – a scientific-research institute based in Paris.

International Air Transport Association
It is a voluntary non-governmental organization of air carriers operating regular international transport.

Main objectives are:

- To help create a single global system of safe, regular and economical air transport;
- To prepare and coordinate actions aimed at improving the economic performance of air transport;
- To ensure and coordinate cooperation between air carriers and other organizations active in the air transport sector;
- To cooperate with ICAO and ensure the implementation of ICAO standards into the practice of all air carriers.

4.4. Important non-governmental organizations with regional scope

AEA (Association of European Airlines) – association of European air carriers

IACA (International Air Carrier Association) – association of European charter carriers

ERA (European Regions Airline Association) - represents the interests of carriers running commercial scheduled flights by small aircraft,

FATUREC (Federation of Air Transport User Representatives in the European Community) – protection of air transport users,

AAPA (Association of Asia Pacific Airlines) - represents the common regional interests of the Far East airlines.

4.5. State administration bodies (Czech Republic)

Ministry of Transport of the Czech Republic (MDCR) - the central state administration body for all modes of transport, including civil aviation.

The Civil Aviation Authority (UCL) - the organizational unit of the state is directly subordinated to the Ministry of Transport of the Czech Republic, which carries out state administration in civil aviation matters.

Air Accidents Investigation Institute (UZPLN) - Independent organizational unit of the state whose function is to investigate and analyze air accidents and to implement measures to prevent accidents.

4.6. State enterprises in civil aviation

Air Navigation Services of the Czech Republic - The principal objective of the ANS is to ensure a safe environment for air traffic, to ensure that there is no collision in airspace and on the ground, to organize a fast, safe and fluid flow of air traffic, and also to respond flexibly to the dynamics of civil aviation development in changing aviation conditions.

Czech Aeroholding, a.s. - a company whose sole shareholder is the state, represented by the Ministry of Finance of the CR. Company operates and manages the international public civilian Václav Havel airport Prague, which is the largest airport in the Czech Republic by the number of checked-in passengers (over 13 million in 2016).

5. THE CLASSIFICATION OF AIRCRAFTS AND FLIGHT PHYSICS FUNDAMENTALS

5.1. Definition of aircraft

Aircraft is a **flying means of transport**, according to the definition of the Czech standard it refers to: "A device capable of exerting forces carrying it in the atmosphere from air reactions that are not reactions to the Earth's surface."

Aircrafts can be divided according to many aspects, but the basic classification is as follows:

- **Aircraft lighter than air** – they use aerostatic forces to fly;
- **Aircraft heavier than air** – in order to fly they mostly use aerodynamic force (lift) on lifting surface that can be moving or fixed (wing).

5.2. Classification of aircraft

- **Aircraft lighter than air (aerostats)**
    - **With propulsion** - for example airships;
    - **Without propulsion**- for example hot air balloons.
- **Aircraft heavier than air (aerodynes)**
    - **Without propulsion with fixed lifting surfaces** (wings) – e.g. a parachute or a glider;
    - **With propulsion with moving (rotating) lifting surfaces** – e.g. a helicopter;
    - **With propulsion with fixed wing/wings** – e.g. a rogalo or a classic airplane;
    - **With propulsion without lifting surfaces** – a rocket.

There are also combinations of the above – e.g. a convertiplane, which changes the method of achieving lift during the flight.

5.3. Classification of transport airplanes

Depending on the length of the flying range we distinguish:

- Short-haul airplanes with a range of up to 1,000 km, sometimes referred to as regional.
- Medium-haul airplanes with a range of 1000 to 3000 km. These aircraft are mainly used on international routes.

- Long-haul aircraft with a range of more than 3000 km are deployed on transcontinental flights.

Depending on seat capacity we distinguish:

- Light aircrafts - aerotaxi: 3 to 10 passengers;
- Small transport airplanes: 10 to 30 passengers (sometimes called as feederliners);
- Medium-sized transport airplanes: 30 to 100 passengers;
- Large transport airplanes: 100 to 200 passengers;
- High capacity aerobuses : over 200 passengers.

Depending on the seat arrangement in the airplane we distinguish:

- Narrow-body airliners – with single aisle, 2-2 or 3-3 seats abreast;
- Wide-body airliners – with two aisles and 2-3-2, 3-3-3 or 3-4-3 seats abreast.

Depending on the type of propulsion system we distinguish:

- Propliners (past) or light airplanes with propeller (piston-powered engines);
- Propjet (Turboprop powered);
- Jet airliner (Turbofan or turbojet powered).

Transport airplanes can also be distinguished according to the location of lifting surfaces, the number and position of the engines, the type of landing gear or the shape of the wings (and others).

5.4. Generation of aerodynamic force

An airfoil generates lift by exerting a downward force on the air as it flows past. According to Newton's third law, the air must exert an equal and opposite (upward) force on the airfoil, which is the lift (Simplified physical explanations).

For aircrafts heavier than air, the aerodynamic force must be equal to or greater than the weight of the flying object.

To generate the aerodynamic lift it is necessary to ensure the airflow around lifting surfaces (wings) at a certain velocity *v*, the wing must also have a certain profile (airfoil) and sufficient area *S*, and it is also necessary to ensure the efficient „angle of attack" of an airfoil.

Fig. 2: An airfoil of aircraft – what is angle of attack?

Aerodynamic force *Y* is generated according to the principles:

$$Y = c_y \,.\, S \,.\, \rho \,.\, v^2 / 2$$

S – size of lifting surfaces [m^2],
ρ – air density [kg/m^3]
v – airplane velocity [km/h]
c_y – „angle of attack α" function – aerodynamic coefficient

6.BASIC DESIGNS OF AIRPLANES

6.1. Airplane components

From a design point of view, the aircraft (transport airplane) can be divided into three relatively separate units:

- **Airframe;**
- **Propulsion unit (system);**
- **Equipment**.

These basic units are further divided into:

- Assemblies that perform the function of basic units;
- Separate functional circuits;
- Aircraft systems (for example hydraulic, electrical system, etc.).

We are dividing the **airframe** on:

- Fuselage;
- Landing gear;
- Lifting surface (wings);
- Tail surfaces.

6.2. Fuselage

The central part of the aircraft, usually with a circular or oval profile (monocoque), providing, inter alia:

- Structural connectivity of main lifting surfaces and tail surfaces into one single unit;
- Location of other aircraft systems, avionics, equipment and aggregates;
- Environment for the placement of passengers, crew and cargo - for airplanes, the fuselage is equipped with a pressurized cabin (flights above 3000 meters above sea level);
- Transfer and distribution of payload on the airplane.

6.3. Lifting surfaces

Lifting surfaces are commonly designated by the term **wing**, where the lift force *Y* is generated.

The wing is provided with systems that are functionally associated with it (see Figure 3).

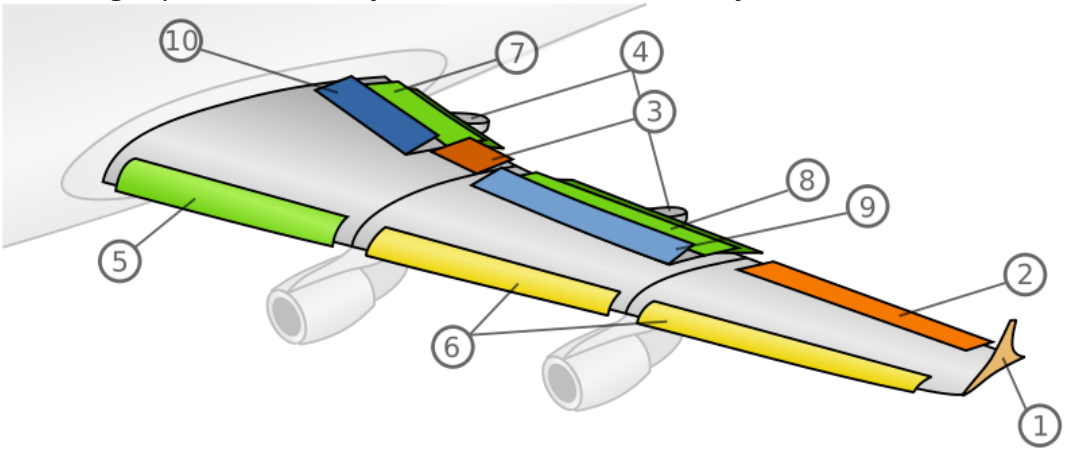

Fig. 3: Wing of an airplane (Author: Arne Nordmann (user:norro), 2006, Illustration based on the illustration Image:PlaneWing.png of Piotr Jaworski (PioM)., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1390944)

Wing Mechanization - A system of movable elements that are controlled either by the pilot or automatically. Other functional surfaces situated on the wings are controlled by this mechanization.

6.4. Functional surfaces on wings

Winglets (1) - are extensions of fixed wing that encourage more efficient use of lift force exerted on the ends of the wings.

Ailerons (2,3) - are a hinged flight control surfaces used in pairs to control the aircraft in roll (or movement around the aircraft's longitudinal axis).

Pods for flaps (4) - streamlining the flap track mechanisms.

Krueger flaps (5) - lift enhancement devices that may be fitted to the leading edge of an aircraft wing.

Slats (6) - aerodynamic surfaces on the leading edge of the wings of fixed-wing aircraft which, when deployed, allow the wing to operate at a higher angle of attack.

Flaps (7, 8) - Sliding devices on the wing of the airplane to increase lift at low speeds,

in the take-off and landing phase of flight.

Spoiler (9) - A hinged plate on the upper surface of the wings, which serves to reduce lift in a controlled way. By so doing, the spoiler creates a controlled stall over the portion of the wing behind it, greatly reducing the lift of that wing section. It is especially useful for landing when, due to reduced lift, the aircraft touches the runway more firmly and pushes the landing gear to surface.

Aerodynamic brake (10) - Increases the aerodynamic drag of the airplane (similar to the spoiler).

6.5. Tail surfaces

Tail surfaces consist of:

- Horizontal tale surfaces;
- Vertical tale surfaces.

Horizontal tale surfaces consists of:

- Fixed part = **Stabilizer** - provides stability and control of an airplane;
- Hinged aft surface = **Elevator** - controls the aircraft's pitch, and therefore the angle of attack and the lift of the wing.

Vertical tale surfaces consists of:

- Fixed part = **Fin** (vertical stabilizer) - is intended to reduce aerodynamic side slip and provide direction stability;
- Hinged aft surface = **Rudder** - allows the pilot to control yaw around the vertical axis.

6.6. Airplane movement in 3D space

Simply put, the transport airplane is controlled in three-dimensional space by a combination of three control surfaces:

- **Ailerons** – Tilts the airplane around its longitudinal axis;
- **Rudder** –deflects the airplane around its vertical axis;
- **Elevator** – deflects the airplane around its horizontal axis.

In practice, both aileron and rudder control input are used together to turn an aircraft, the ailerons imparting roll, the rudder imparting yaw, and also compensating for a phenomenon called adverse yaw. A rudder alone will turn a conventional fixed-wing aircraft, but much more slowly than if ailerons are also used in conjunction.

7. PROPULSION SYSTEMS OF AIRPLANES

7.1. Propulsion unit

The propulsion unit is one of the important elements of the airplane because it generates its thrust. Important parts of the propulsion unit include:

- Propulsor – aircraft engine, which generates mechanical power;
- Air intake and flue gas outlet;
- Propeller (only piston engines or turboprop engines);
- Wheels and axles, thrust reversing devices and other.

The most used engines for transport airplanes can be distinguished by:

- **Shaft (piston) engines with propeller** – used on small airplanes only;
- **Reaction engines** – turbojet or turbofan;
- **Combination** – turboprop.

7.2. Turbojet

Its basis is the turbo compressor part. Part of the exhaust gases energy is converted into mechanical energy on the turbine shaft. With even engine running, turbine power is fully consumed to drive the compressor. The compressor provides the desired air mass flow rate of the turbo-compressor engine part and its compressing to the desired value. The energy status of the gases (exhaust gases) at the outlet is higher, the exhaust gases provide part of the energy to accelerate the aircraft.

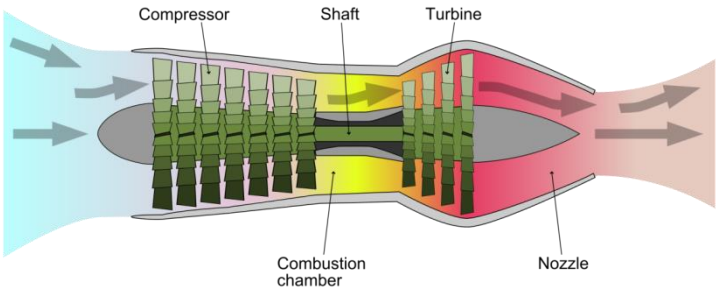

Fig. 4: Turbojet (Source: CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=7586542)

7.3. Turbofan

Turbofan is a type of aviation engine that works on a similar principle as a jet engine, that is, on the principle of action and reaction law. In contrast to the jet engine, it also contains a fan and a low-pressure compressor driven by another turbine. The air entering the engine is first pressed by the fan. Its part (given by bypass ratio) flows into the high-pressure part of the engine, but the rest flows through the so-called bypass channel. The engine thrust is caused by the effect of both gas streams.

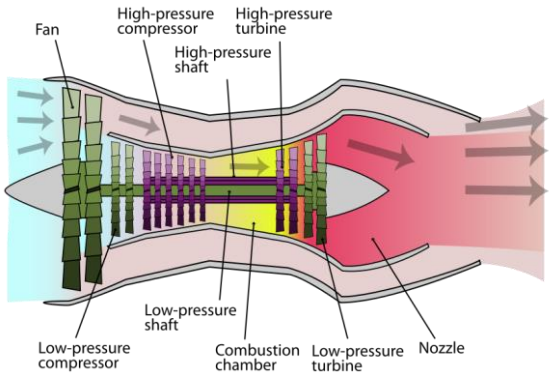

Fig. 5: Turbojet (Author: K. Aainsqatsi – Vlastní dílo, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4008470)

7.4. Turboprop

The exhaust gases flow from the turbocharger (generator) part transmits a substantial part of its energy to a low pressure turbine for propeller propulsion. The residual tensile force of the exhaust gases in the outlet nozzle is very small. The tensile force of these motors is from 85-90% created by propellers. Because the speed for maximum propeller efficiency is lower than that of the turbocharger rotor and propeller turbine, it is necessary to use a reducer.

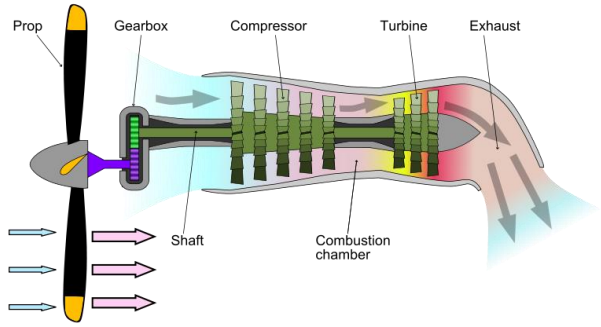

Fig. 6: Turbojet (Source: Turboprop_operation.png: Emoscopesderivative work: M0tty (talk) – Turboprop_operation.png, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=7611409)

8. AIR TRANSPORTATION PROCESS

The air transportation process can be referred to as the sum of the stages that passengers pass during the use of air transport. The overall impression, comfort, and speed of the air transport process is influenced by other indirectly related stages that passengers have to undergo in order to participate the flight.

- Transport to the airport
- Check-in
- Security check
- Waiting for the departure
- Boarding the plane
- Services on board
- The actual air transport
- Exit to the terminal
- Departure from the airport

8.1. Passenger check-in

The check-in process of the passenger is intended to ensure that boarding the airplane is only allowed to passengers who have:

- confirmed reservation and fare paid for the flight;
- personal, visa, health documents corresponding to the requirements of the receiving state;
- the number, volume, or weight of checked-in baggage corresponding to the paid fare;
- number, size, weight, and contents of cabin baggage corresponding to the safety regulations and regulations of the carrier.

8.2. Check-in process

- Passengers present a ticket from which a flight coupon corresponding to the section of his journey is taken.

- Passengers present an ID (national ID card, passport).

- Passengers' luggage is taken over to carry and they are offered a seat corresponding to the paid fare and personal preferences (in case of vacancies).

- Passengers are alerted to safety regulations and are asked questions related to ensuring the safety of their luggage contents.

- Passengers receive a boarding pass and luggage ticket.
- The boarding pass is then presented together with the prescribed personal identification document for inspection by the state passport authority (for passengers traveling to countries with a visa requirement).

From the point of view of the organization of check-in, the following types of check-in are usually used:

- Common check-in - at the counters it is possible to check-in for any line of scheduled airlines departing in a certain period of time (e.g. 12 hours, 24 hours, 6 hours).

- Flight or company check-in - individual counters or a certain number of counters are intended to check a particular flight or multiple flights of a particular company.

- Express check-in - is only for passengers without registered luggage and is specially marked.

- Gate check-in - check-in right at the exit. It can only be used if the passenger, including luggage, has already been checked in earlier, e.g. in a city office or hotel.

- Self-check-in - Passengers usually identify themselves with their payment card, and they check in for the flight themselves using interactive communication with the check-in facility. The checked baggage is handed over at the drop off counter.

- Internet check-in - allows the passenger to check in before traveling to the airport. The checked baggage is handed over at the drop off counter.

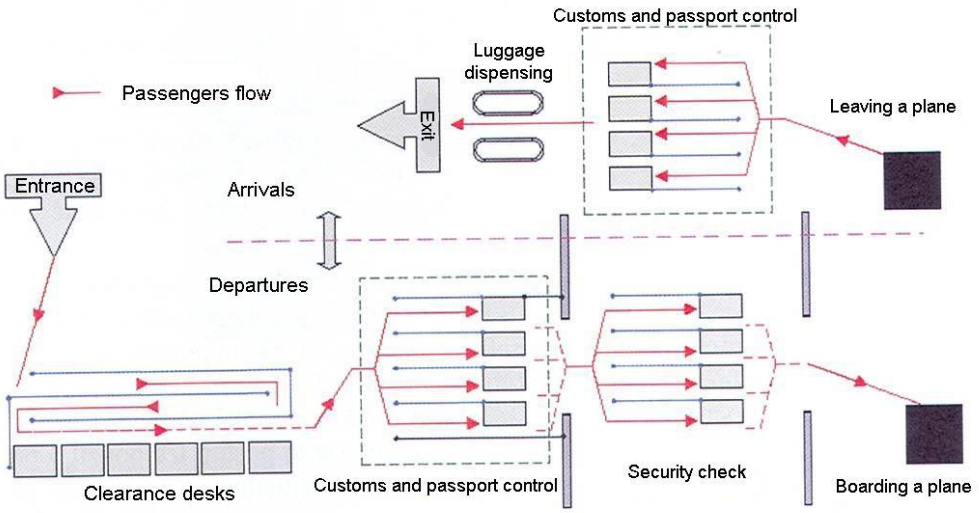

Fig. 7: The process of passenger check-in at departures and arrivals.

8.3. Aircraft ground handling

Aircraft ground handling defines the servicing of an aircraft while it is on the ground and (usually) parked at a terminal gate of an airport. Many airlines subcontract ground handling to airports, handling agents, or even to another airline.

- Cabin service - the crew is cleaning the airplane before the flight and supplies onboard consumables.

- Catering - includes the unloading of unused food and drink from the aircraft, and the loading of fresh food and drink for passengers and the crew.

- Ramp service - This includes services on the ramp or apron, for example:

    - Electric power supply (plugging/unplugging the Ground Power Unit GPU);
    - Refueling;
    - Passenger stairs (or airbridge);
    - Airstart units;
    - Deicing;
    - Guiding the aircraft into and out of the parking position (by way of aircraft marshalling);
    - Towing with pushback tractors, and others.

9. AIRLINE BUSINESS MODELS

9.1. Airline business models – basic distribution

Based on regularity

- **Scheduled** - Flights according to the flight schedule
- **Non-scheduled** - Charter or leisure airlines

Based on served markets

Domestic
International (US vs EU approach)

Based on payload type

- **Passengers** - traditional airlines vs. Low-Cost Carriers model (LCC)
- **Combi** - cargo on the main deck behind the passengers' area and in the belly
- **Cargo**
- **Mail**
- **Integrators**

9.2. Air routes network conceptions

There are two very different ideas for planning flight routes:

- **Hub-and-Spoke model (H&S);**
- **Point-to-Point model (P2P).**

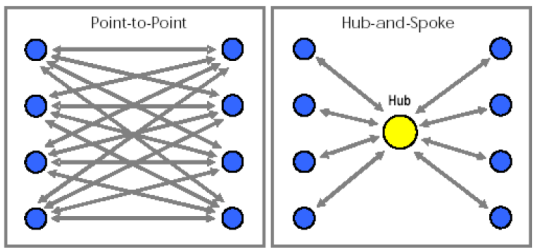

Fig. 8: Basic air routes network conceptions (Source: Rodrigue et al., 2006)

Hub-and-Spoke (benefits):

- Significantly less routes are needed to serve the network.
- Since there are less routes, assuming the number of planes are the same, airlines can schedule more frequent flights along each route and make full use of the capacity of each plane.
- Centralizing operations at the hub leads to economies of scale.

Point-to-Point (benefits):

- Minimizes connections and travel time.
- No interdependency of flights and hubs – a delayed flight or a closed airport will not significantly affect other flight schedules.

9.3. Traditional passenger airlines

Main features:

- Seat capacity is offered to general public according to published schedule;
- Hub and spoke system;
- Traditional services (2-3 classes, food and beverages, on-board entertainment, business lounges, frequent-flyer programmes, other);
- Offering of flights via travel agents;
- Cooperation with other airlines – multisector tickets offered also on flights of partner airlines (complex revenue management);
- Transfer flights.

9.4. Low-Cost Carriers (LCCs)

How is it possible they are offering flight tickets for low prices? (main examples)

- Operating at costs consistently below its revenues;
- Strategy of operating short sectors, low and unrestricted fares, high point-to-point frequencies, excellent punctuality;
- No traditional frills such as free meals, pre-assigned seats or connecting flights;
- Mainly using secondary airports – lower airport charges;
- Operating aircraft longer hours – spreading fixed costs over more hours;
- Mainly using single type fleet (of economic aiplanes with high density seats);
- Mainly using on-line booking;
- Selling the meals, drink and souveniers on-board.

9.5. Charters

Main features:

- Low cost model – no frills, high seat density;
- Whole capacity sold to the customer (usually travel agencies or interest clubs) under a "charter contract";
- Competitive pricing based on real costs but also external factors;
- Low utilisation during winter season (wet lease as solution);
- Very high utilisation during tourist season (15 to 17 hours);
- Absolute necessity of flying during the night;
- Customer responsible for using the seat capacity;
- Customer's choice of destinations.

9.6. Cargo airlines – all airplane capacity for freight

- General (or heavy) air freight
    - larger commodities;
    - traditional airport-to-airport services (pure cargo carriers - for example CargoLux);
    - around 85% of the total.
- Express freight
    - integrated door-to-door services (Integrators - for example FedEx, UPS, DHL, TNT);
    - around 11% of the total.
- Mail
    - distribute as part of the national mail system;
    - international shipping by airlines contracts;
    - around 4% of the total.

9.7. Global Alliances of airlines

The highest form of cooperation, especially of traditional passenger airlines - the globalization of offer and distribution of air transport services. Main features:

- Coordination of Alliance partners flight schedules;
- Harmonization of seat capacities offered on flights;
- Unification of reservation and check-in systems;
- Offering of continual prices of tickets to Alliance destinations;
- Creating a common "frequent flyer program" (FFP);
- Alliance offer of additional services to passengers;
- Unification of the fleet and repair capacities;
- Integration and sharing other activities.

10. AIR TRANSPORT INFRASTRUCTURE

Air transport infrastructure includes buildings, objects and facilities that have a direct impact on the organization and management of air traffic in the airspace or on the ground, or allow the movement or servicing of aircraft on airports. It is possible to divide the infrastructure into three parts:

- Airspace is an 3D space above the territory of the State to a height that can be used for air traffic. Airspace is open to flying under the conditions laid down by the laws of each state and international treaties ensuring flight rules which lay down procedures for moving in the airspace.
- Airport consisting of a territorially defined and suitably adapted area, including buildings and facilities permanently destined for take-off and landing of aircraft and aircraft movements related thereto.
- Air services to ensure the security and continuity of flights in the airspace of each states.

10.1. Airport - classification

In the Czech Republic, airports are divided into the following categories:

According to technical conditions, operating conditions and basic purpose:

- **Domestic airports** - are intended and equipped to carry out domestic flights only (within one state);
- **International airports** - are designed and equipped not only for domestic flights but also for flights crossing the state border of the state - they are equipped with passport, customs, health and other controls.

According to the group of users:

- **Public** - an airport which can accept all aircraft by its operational capability;
- **Non-public** - airports for which the user group is designated by operators proposal;
- **Military** – Airports that serve only for the army needs.

According to the nature of the air traffic at the airport:

For example transport airport, sports airport, corporate airport, experimental airport, for agricultural purposes and others.

10.2. Airport – Movement areas

Movement areas are asphalt or concrete (most common) surfaces for the movements of aircrafts. We can divide them into:

- **Runway (RWY)** - defined rectangular area on a land aerodrome prepared for the landing and takeoff of aircrafts.
- **Taxiway (TWY)** – path for aircraft at an airport connecting runways with aprons, hangars, terminals and other facilities.
- **Apron (APN)** – The area near the terminal and hangar equipped with aircraft stands for carrying out aircraft handling, loading and unloading goods, embarkation and disembarkation of passengers, etc.

Runway (RWY) can be divided into categories:

- **Non-instrument RWY** - intended for the operation of aircraft using visual approach procedures (VFR).
- **Instrument RWY** – intended for the operation of aircraft using instrument flight rules (IFR) – instrument approach procedures.

10.3. Airport - operating facilities

In addition to the technical facilities for organizing air traffic (especially in the phase when an airplane approaches the RWY), airport visual and navigational aids are available at the airport, which at the same time allow operation of air traffic at reduced visibility at airports:

- Indicators and signals (for example Wind Direction Indicator);
- Marking on movement areas (for example threshold, distance or axial marks on the runway);
- Lighting systems (instrument RWY only):
    - **Approach lighting systems** - For visual guidance of the aircraft onto the RWY;
    - **Precision approach lighting systems** - provides guidance information to help a pilot acquire and maintain the correct approach (in the vertical level) to an

airport (for example PAPI system);

- **RWY lighting systems** - Lighting defines for example the boundaries or RWY center line.

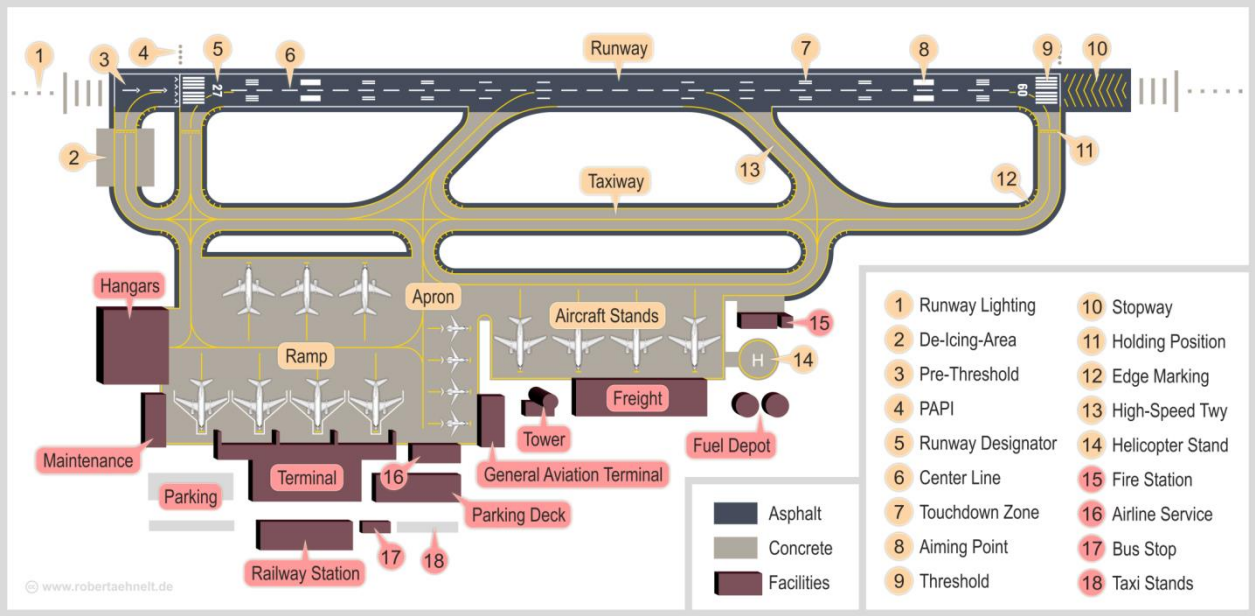

Fig. 9: Civil aviation airport infrastructure (Author: CellarDoor85 (Robert Aehnelt). - Own work., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=16561926)

10.4. Airport terminals

Airport terminal is a building at an airport where passengers transfer between ground transportation and the facilities that allow them to board and disembark from aircraft. Within the terminal, passengers purchase tickets, transfer their luggage, and go through security.

The division of the terminal parts into:

- Departure and arrival section;
- Pre - security section – The public part of the terminal where the free movement of persons is allowed;
- Post security section – Non-public part of the terminal with areas for the movement of persons who have passed check-in, customs, security and passport control.

10.5. Air Traffic Control

Air Traffic Control (ATC) is a service provided by ground facilities to aircrafts in a controlled airspace or a controlled airport. The basic purpose of air traffic control is to prevent collisions in the air and on the ground, but air traffic controllers usually provide pilots with other services such as navigation assistance or information services. The air traffic control service is usually provided by three mutually cooperating specialized centers:

- Tower control (TWR) - Controllers in the tower are responsible for safe traffic operation on the runway, taxiways and in a Controlled Zone (CTR), which is an airspace in the immediate vicinity of the airport.

- Approach control (APP) - Its mission is to maintain safe and continuous air traffic in the terminal-controlled area, which is the airspace in the wider area of the airport.
- Area Control Centre (ACC) - Provides air traffic control in the respective controlled area, typically a large area of controlled airspace, sometimes covering the whole of the country.

10.6. Airspace

We recognize two basic types of airspace in terms of movement within it (i.e. flying):

- Controlled airspace;
- Uncontrolled airspace.

In the context of air transport, airspace is further divided into different areas, segments, banned areas, temporarily reserved areas, etc., defining the airborne air route.

The flights themselves are coordinated by dispatchers of Air Traffic Control (ATC), who supervise, inter alia, the vertical and horizontal spacing between individual aircraft in controlled airspace.

11. AIR FREIGHT TRANSPORT

11.1. Air Cargo – basic forms

- Additional transport of cargo on scheduled passenger flights, using the spare volume in the airplane's baggage hold (the "belly") that is not being used for passenger luggage.

- Scheduled freight transport by cargo aircraft. This method is operated by large aircrafts dedicated for the job.

- Charter based cargo transport - ie. renting all capacity in cargo aircraft. It is often used in the transport of live animals, emergency supplies during natural disasters and the like.

Forms of freight:

- Separate shipments;
- Unit load device – pallets or containers for air transportation;
- Combination.

11.2. Acceptance of goods for air transport

General conditions and steps:

- The sender (consignor) agrees to the shipping conditions of the airline (for example IATA conditions of carriage for cargo) – type of cargo must comply with the general conditions.

- Goods received for carriage must meet all requirements (for example properly packed consignment, whether documents are required, etc.).

- Shipments of a special nature must also meet all the specific requirements for the transport of each type of commodities.

- Transportation of specific goods is not prohibited by laws or regulations of the countries concerned.

- An air carrier's worker or its agent, after checking the goods, chooses an appropriate

tariff and issues the air waybill (AWB) to the customer. The rate is calculated according to the Air Cargo Tariff and Rules (TACT) or a special tariff is selected.

11.3. Air Waybill (AWB)

It is the most important document in air freight transport issued by an air carrier or its agent. The basic functions of AWB are as follows:

- Verified by the consignor and the carrier is proof of the conclusion of a transport contract between the consignor and the carrier;
- AWB is a proof of receipt of goods for carriage;
- AWB is also an invoice;
- AWB is proof of payment of premiums;
- AWB is also a customs declaration;
- AWB is a source of information (from when does AWB apply, cargo handling, dispatch and delivery of shipments, etc.).

The air waybill consists of 3 originals and copies. Originals acquires major carrier, sender (consignor) and consignee (at the destination). The remaining copies will be received by the entities involved in the transportation process.

11.4. The Air Cargo Tariff and Rules TACT

- The tariff for air freight is governed by the TACT document, which sets rates per kilogram of freight or minimum flat rates for given transport routes. The calculation of the shipping cost has its own rules, the type and dimensions of the cargo are taken into account. These are rates for goods:

- General Cargo Rates (GCR) – are applied to the carriage of goods not included in another class.

- Specific Commodity Rates (SCR) - are used for a certain type of goods, specified by the four-digit code in the TACT.

- Class Rates (CR) - These rates are only used for goods listed in the TACT document. These goods are:

    - Live animals, valuables, human remains in coffins and urns, newspapers and Periodicals, unaccompanied baggage sent as cargo, and others.

Special tariff concepts:

- „Home-to-Home“ tariff,
- Express tariff,
- flat rate per piece / unit,
- Contractual rates,
- Tariff for air containers and pallets (ULDs)

Additional charges, such as a fee for issuing an air waybill, customs clearance, a certificate of origin, etc. may be charged for the shipment transport.

11.5. Unit Load Devices (ULDs)

These are unified air containers and pallets approved by IATA. The price for the transport of containers and pallets is valid up to the specified weight limit („Pivot weight).

- Air freight container is a compact box, which can be made from different materials (molded paper, fiberboard, metal, plastics). The walls of the container are firm. The container forms a single unit for the transport of large quantities of packages (general cargo).

- The pallet is a platform made of compact or non-compact material on which individual shipments are deposited, so that the whole constitutes one load unit. The pallet has handles and the goods are fastened to it by means of mesh.

Container type	Volume	Linear dimensions (base width / overall width × depth × height)
LD1	4.90 m^3	156 / 234 × 153 × 163 cm
LD2	3.40 m^3	119 / 156 × 153 × 163 cm
LD3	4.50 m^3	156 / 201 × 153 × 163 cm
LD3-45	3.50 m^3	143 / 243 × 142 × 109 cm
LD6	8.95 m^3	318 / 407 × 153 × 163 cm
LD8	6.88 m^3	244 / 318 × 153 × 163 cm
LD11	7.16 m^3	318 × 153 × 163 cm
Pallet type	Volume	Linear dimensions
LD8	6.88 m^3	153 × 244 cm
LD11	7.16 m^3	153 × 318 cm
LD7 (2 pallet variants)	10.8 m^3 11.52 m^3	224 × 318 cm 244 × 318 cm

Tab. 1: Examples of unified ULDs and their characteristics

11.6. Cargo terminals at airports

Cargo terminals for air freight are used for storage and handling of shipments (among others). Cargo terminal must be equipped with the following in particular:

- **Truck center** - Each terminal must be connected at least to road transport infrastructure, there is a direct automated transloading of the palletized units from the aircraft to the trucks and vice versa.
- **Automated warehouse for air freight containers and pallets equipped with forklift loader** - similar to other logistics centers and terminals in other transport modes.
- **X-ray equipment** for checking larger size shipments.

- **Refrigeration and freezing areas** for storage of perishable shipments.
- **Other special areas** - such as areas for live animals, dangerous goods or radioactive shipments.

12. AIR FREIGHT SHIPMENTS

12.1. Air Cargo – Types of shipments

- Separate consignments (shipments) and shipments loaded into containers (ULD) as subsidiary transport on scheduled flights in transport airplanes for passengers, their luggage and mail.

- Separate consignments (shipments) and shipments loaded into containers or pallets (ULD) - Cargo shipments transported within scheduled or non-scheduled air cargo routes (mostly All Cargo carriers who focus only on pure freight).

Another categorization of shipments:

- Non-Special Consignments (low-value items);
- Shipments requiring special care.

12.2. Shipments of a special nature

For these items, it is necessary to request transportation in due time, especially due to "booking" of the space in the aircraft for the consignments. In particular, such items include:

- Transport of dangerous goods - Carried out according to IATA Dangerous Goods Regulations (IATA DGR).

- Transport of live animals - Carried out in accordance with the specific IATA regulations (LAR Manual) that the shipper and the participating airline must observe for transport. The LAR Manual determines e.g.:

    - Veterinary regulations of individual countries
    - Transport box requirements (space, double bottom, ventilation...)
    - The presence of the animal keeper
    - Vaccination
    - Documentation, etc.

- **Transport of perishable goods** – include goods which can change their properties due to temperature, therefore require special care during transportation. The consignments must be labelled with “Perishable” label and if the item contains liquids, “This Side Up” label is attached as well.

- **Transport of valuable items** - These are objects and goods, otherwise referred to as valuable, expensive, protected, etc. In particular, it includes all goods in the price of 1000 US dollars or more.

- **Transport of fragile and easily breakable items** - Requires special attention during handling and transport. It must be packed in two inner and outer layers, the interspace must be filled with shock-absorbing material. The consignments must be labeled with “Fragile Handle with Care” label.

- **Transport of goods that may not be turned upside down** - must be labelled with "This Side Up" label. They most commonly include liquids, which are to be packed in two containers; the interspace is filled with absorbent material; the liquid is filled to 9/10 of the container content.

- **Transport of human remains** - Cremated human remains must be accompanied by a certificate of cremation. Non-cremated remains can only be transported in a sealed lead or zinc coffin, which must be further stored in a wooden coffin. It can be further wrapped or covered with a canvas so that the nature of the shipment is not obvious. Remains are always transported in a separate cargo compartment of the aircraft, separate from other goods.

- **Transport of weapons and ammunition** - Weapons of all kinds may be accepted for international transport to such countries where permitted by applicable regulations, and only if the consignment is accompanied by all documents required for export, import and transit, and if its acceptance to transport is not inconsistent with the transport regulations of the participating carriers. The ammunition is accepted for transport under the conditions laid down by the IATA DGR. Extreme security measures are valid for the export of such consignments.

- **Transport of damp goods** - Damp goods (where fluid or moisture may escape during transport) are only accepted for transport in watertight containers. These are mainly refrigerated goods, fresh wet flowers, fruits and vegetables.

- **Transport of bulky goods** - accepted for transport on condition that they fit into the cargo compartment of the aircraft and that there is a free space available.

- **Transport of partial shipments** - If a larger weight consignment consisting of several pieces cannot be loaded into one plane, it can be divided into several parts and transported one-by-one by two or more aircraft of the same airline.

- **Transport of heavy goods** - These are shipments exceeding the maximum weight per m2 of floor. Such consignments must be deposited on underlying materials in order to spread the weight on a larger surface.

- **Unaccompanied baggage or baggage shipped as cargo** – If passengers exceed the free baggage allowance (20 kg or 30 kg), they pay the surcharge on the excess baggage. In addition, passengers are allowed to carry a certain baggage as unaccompanied, thus making cargo from the baggage.

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